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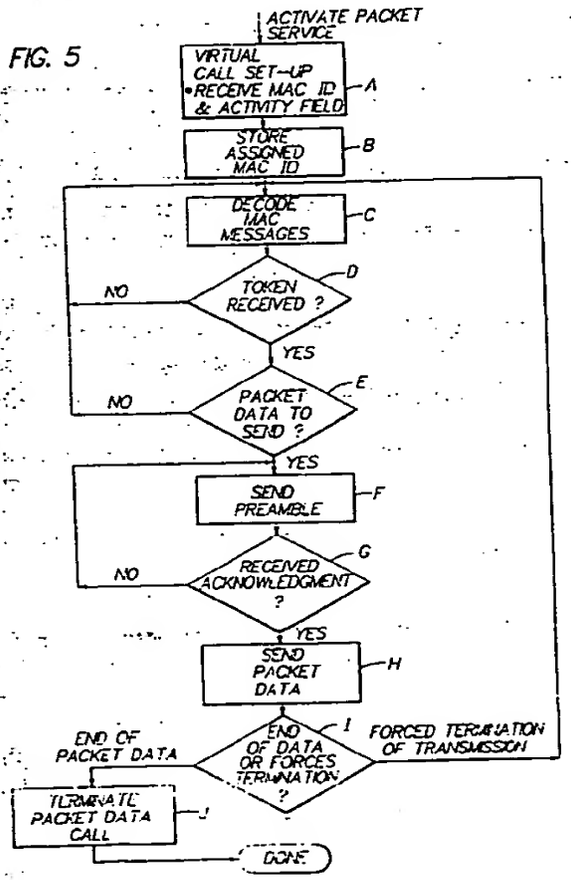
(54) A method for scheduling packet data transmission

(57) In a packet data transmission and reception system a media access control (MAC) message is broadcast by a base station to a plurality of mobile stations. The MAC message contains packet data transmission scheduling information which allows the base station to preemptively control mobile station access to traffic channels in order to maximize the efficiency of packet data transmissions and allow scheduling consideration including priority access, quality of service and maximum bytes per transfer. The MAC message consists of a control frame structure which comprises scheduling parameters including MAC IDs fields, activity fields, and a field representing the number of free traffic channels in a cell. These parameters enable multiple mobile stations to share, in a time multiplexed fashion, traffic channels for packet data transmission on CDMA based mobile communication systems.

FIG. 5



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Description

This invention relates to cellular telephone network data transmission, specifically to a method of scheduling packet data transmission for a connection-less packet service.

Packet data communication is known in cellular telephone systems, as is evidenced by, for example, commonly assigned U.S. Patent No.: 5,257,257, issued October 26, 1993, entitled "Method of Controlling the Operation of a Packet Switched CDMA Communication Network for Controlling the Operation of Transmitters and Receivers", by X.H. Chen and J. Oksman.

One further example is defined in TIA/EIA/IS-657, Packet Data Service Option for Wideband Spread Spectrum Cellular System. IS-657 is used along with TIA/EIA/IS-95A, Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System, and, TIA/EIA/IS-99 Data Services Option Standard for Wideband Spread Spectrum Digital Cellular System. The current IS-657 based packet data scheme for code division multiple access (CDMA) does not allow the traffic channel to be shared between more than one user. The IS-657 scheme is based on a make-and-break of multiple traffic channel connections during the life of a packet data session. In the worst case, a packet may suffer a call set-up delay which can range from tens of milliseconds to a few seconds. Also, it is possible for a mobile station (MS) to transmit idle (eighth rate) frames for a user defined time if there are no packets to send. This results in wasted bandwidth, especially in high-speed data systems, because the traffic channel capacity is reserved for this user and cannot be utilized by any other user. Thus, an access scheme that allows two or more users to share traffic channels, and allows the network to control the packet delay is needed.

In connection-less packet data transmission in mobile communication systems, discrete packets are transmitted on a packet-basis, that is, no dedicated end-to-end connection is set up. Sharing of traffic channels in connection-less packet data transmission has generally been supported via random access or random reservation media access control (MAC) protocols. Under these MAC protocols, multiple mobile stations compete for traffic channels in order to receive packet data service from a base station (BS). The number of available traffic channels for packet service within a cell is defined by the BS.

Random reservation protocols are generally believed to offer high channel utilization. However, in a CDMA based system that is approaching the system's maximum capacity, random access attempts are more likely to be unsuccessful due to higher interference levels. Thus, as a cell approaches its maximum capacity of available traffic channels, multiple MSs compete for fewer and fewer available traffic channels. This normally leads to even further access attempts by the MSs. Often, the random attempts themselves increase the communications load in the cell and reduce traffic channel capacity.

It is a first advantage of this invention to provide an efficient method for transmitting packet data over a cellular communication network that mitigates the foregoing and other problems.

Another advantage of this invention is to maintain scheduled traffic channel sharing among multiple packet data users who are attached to a cell of a mobile communication network.

Another advantage of this invention is to provide the base station of a cellular communication network with control over which mobile station(s) may attempt access to the system during a specified period of time.

Another advantage of this invention is to provide the base station of a cellular communication network the ability to preemptively control priority and duration of mobile station access by employing a scheduling method which considers one or more parameters including priority access service, quality of service, and a maximum number of bytes per transmission.

The foregoing and other problems are mitigated and the performance of this invention is realized by methods and apparatus in accordance with embodiments of this invention. More particularly, this invention is directed to solving the problem of inefficient packet data transmission in CDMA based mobile communication systems.

Scheduled packet access, as taught by this invention, leads to more stable load conditions, offers higher channel utilization, and enables determination and control of a maximum delay in packet data transmission experienced by users. According to the teachings of this invention, the BS divides access to the traffic channel(s) allocated for packet data services into time slots. The right to access a given traffic channel for a specific time slot is referred to as a packet token, hereinafter simply a token. One or more token(s) are allocated to the MSs from time slot to time slot, in a pre-defined manner. The token allocation schedule is determined at the BS, which may employ a variety of schemes to determine how the token is assigned. This pre-defined, scheduled token allocation is distinguishable over conventional random access and random reservation protocols. Token allocation, as taught by this invention, is accomplished by granting transmission access to an available traffic channel to each packet data MS in the cell according to specific, scheduled time intervals. This scheduled approach allows the BS to preemptively control traffic channel access among packet data MSs. Random access protocols, on the other hand, allow access to an available traffic channel as a packet data MS requests it. Thus, the conventional random protocols employ a first-come-first-serve method of traffic channel access assignment.

Allocating the right to access an available traffic channel may not always result in a transmission from the packet data MS. If, at the end of a time slot, the BS

a valid transmission from the MS(s)
! the token(s), either because the MS
ıd or an access preamble did not reach
:lly, then the BS allocates the token to
the cell. In this way, the MSs share the
annels in a time-multiplexed fashion,
lules and controls the allocation of the
at all times. This technique eliminates
sociated with conventional MS random
to gain a traffic channel for transmitting

on preferably employs a technique in
smits at least one dedicated MAC chan-
ward link. When transmitting the MAC
ges to a specific MS the BS may use a
onic serial number (ESN) of the MS as
sk, and when broadcasting MAC channel
MSs within a cell the BS preferably uses
ode mask. The MAC channel messages
data traffic channel information and sta-
on the allocation of the token(s) to packet
in the cell. The MAC channel messages
reflect the latest token usage. By decod-
MAC channel message a MS evaluates
oken(s) for the next time slot, and is able
en it should next be allocated the token
The MS holding a token may attempt to
ffic channel if it has data to send. The MS
es its own private long code for reverse link
as the BS expects a preamble signal from
rently holding a token. Every packet traffic
a pre-defined Walsh code associated on
ink to which the MS listens to determine
ccess was successful. After an access ac-
ent is received from the BS, the MS termi-
eamble and starts to transmit its packet da-
nt, the MS may negotiate the traffic channel
n the BS. The initial traffic channel data rate
ed by a Service Option and may be as low
ined low speed data service, such as 9.6

ccupied, the traffic channel is preferably al-
ıat MS until the end of the packet. The max-
a MS is allowed to occupy a channel is pre-
the network, so that the BS can predict worst
ıel usage. The BS may employ various tech-
nsure efficient channel usage. For example,
gning a token, the BS may define a maximum
bytes that a MS may transmit. If this maxi-
ber of bytes per transmission is exceeded, the
e option to terminate a packet transmission by
transmission stop bit on the associated for-
traffic channel. If the transmission is stopped,
linquishes the token at the next time slot and
e pool of MSs awaiting the next available to-
larly, if the transmission of packet data com-
e MS yields the token at the next time slot.
chniques for monitoring transmissions may be

based on equal sharing between MSs, or allow for different priorities of transmission which depend on the quality of service selected.

In accordance with the present invention, the BS allows the MS to turn off its receiver and save power during the periods when the MS does not hold the token. If the MS does shut down its processing between tokens the BS informs the MS, before the MS shuts down, when it should start its processing again, i.e. when the MS will be allocated the token again. This notification by the BS before the MS shuts down is possible as the token is assigned in advance. Thus, a "dynamic slotted mode" operation is provided, the operation being dynamic in that the position of the slot need not be the same in every cycle. The slot position is a function of how many active MSs are on the channel, and on how much data each MS can transmit. Additionally, the number of slots is a function of the number of available channels at the BS.

The BS may transmit packets destined for a MS, if any, or fill data, on the forward link at the same time that the MS is allocated a token and is transmitting packets on the reverse link. This allows the BS to send power control information to the MS.

According to a first aspect of the present invention, there is provided a method for transmitting packet data from a plurality of mobile stations to a base station, comprising the steps of:

broadcasting media access control (MAC) information from the base station to the plurality of mobile stations;

receiving the broadcast MAC information at the plurality of mobile stations; and

for a mobile station specified in the MAC information, transmitting packet data to the base station at a time specified by the MAC information.

According to a second aspect of the present invention, there is provided a cellular communication system, comprising:

a plurality of base stations, each base station having an associated cell;

a plurality of mobile stations located within said cells;

means in each said base station for broadcasting media access control (MAC) information from said base station to mobile stations located within the base station's cell;

each of said mobile stations comprising a receiver for receiving said broadcast MAC information; and

each of said mobile stations further comprising a

controller, responsive to said broadcast MAC information, for transmitting packet data from said mobile station to said base station at a time specified by the received MAC information.

According to a third aspect of the present invention, there is provided a method of scheduling the wireless transmission of packet data between a mobile station and a base station, comprising the steps of:

assigning an identification to and an activity status for each packet data service mobile station within a cell;

setting the activity status of the packet data service mobile station for queuing the mobile station for packet data transmission;

scheduling packet data transmission times for multiple queued mobile stations;

activating with a media access control (MAC) message a queued mobile station by assigning, with the identification, a right to transmit packet data;

updating the activity status and activation scheduling information in a next MAC message;

broadcasting with a MAC message a packet data transmission scheduling sequence which comprises the updated activity status and activation information to each active packet data service mobile station

decoding in each active packet data service mobile station the broadcast activity status and activation information to determine the scheduling sequence;

predicting a time period when the mobile station has permission to transmit packet data by evaluating the decoded activity status and activation information: and

transmitting packet data during the predicted time period according to the broadcast scheduling sequence.

According to a fourth aspect of the present invention, there is provided a method of scheduling transmission of channel packet data between a packet data source and a packet data sink in a wireless transmission/reception system, comprising the steps of:

establishing time slots for transmitting packet data by dividing access to traffic channels allocated for packet data communication into discrete time periods:

establishing an identification number (MAC ID) for packet data sources to be used for packet data transmission;

associating an activity field with each MAC ID;

using a MAC control frame structure to convey packet data transmission scheduling information from the packet data sink to queued packet data sources, wherein the scheduling information includes activity fields, a Next MAC ID field which specifies a packet data source having a MAC ID to be given traffic channel access in a next time slot, and a count of a number of free traffic channels available at the packet data sink;

activating a queued data source by assigning the Next MAC ID field the value of the data source's MAC ID, thus granting a right to transmit packet data in the next time slot;

updating the activity field of the activated data source and decreasing the count of the number of free traffic channels;

broadcasting the MAC control frame structure to all packet data sources;

predicting at the packet data source the time slot when a given packet data source can transmit packet data by evaluating the MAC control frame structure; and

transmitting the packet data according to the access/transmission scheduling sequence defined within the MAC control frame.

According to a fifth aspect of the present invention, there is provided a method for conserving power in a mobile station, comprising the steps of:

broadcasting media access control (MAC) information from a base station to a plurality of mobile stations;

receiving the broadcast MAC information at the plurality of mobile stations;

for a mobile station specified in the MAC information, transmitting packet data to the base station at a time specified by the MAC information; and

simultaneously receiving packet data from the base station, as the mobile station is transmitting packet data to the base station.

According to a sixth aspect of the present invention, there is provided a method for transmitting packet data

from a mobile station, comprising the steps of:

transmitting media access control (MAC) information from a plurality of base stations to the mobile station;

receiving the MAC information from the plurality of base stations at the mobile station; and

executing a virtual soft handoff with the mobile station by selecting a base station from the plurality of base stations transmitting MAC information to the mobile station according to at least one signal reception condition and, for a time interval specified by the MAC information of the selected base station, transmitting packet data from the mobile station only to the selected base station.

According to a seventh aspect of the present invention, there is provided a method for transmitting packet data from a mobile station to two or more base stations, comprising the steps of:

transmitting media access control (MAC) information from the two or more base stations to the mobile station;

receiving the MAC information from the two or more base stations at the mobile station;

selecting a base station from the two or more base stations transmitting MAC information to the mobile station; and

for a time interval specified by the MAC information of the selected base station, transmitting packet data from the mobile station to the selected base station.

According to an eighth aspect of the present invention, there is provided a cellular communication system, comprising:

two or more base stations, each base station having an associated cell;

a mobile station capable of transitioning from a first cell to a second cell;

means in each of said two of more base stations for transmitting media access control (MAC) information to said mobile station;

said mobile station comprising a receiver for receiving said transmitted MAC information and means for selecting one of said base stations; and

said mobile station further comprising a controller, responsive to said MAC information, for transmitting packet data from said mobile station to said selected base station for a period of time specified by said MAC information received from said selected base station.

The above set forth and other features of the invention are made more apparent in the ensuing Detailed Description of the Invention when read in conjunction with the attached Drawings, wherein:

Fig. 1 is a block diagram of a cellular terminal that is suitable for practicing this invention;

Fig. 2 depicts the terminal of Fig. 1 in communication with a CDMA cellular network;

Fig. 3A is a pictorial representation of a media access control (MAC) channel frame structure employed, in accordance with the invention, by the BS to broadcast packet data traffic channel information and token allocation information to each MS;

Fig. 3B is a pictorial representation of the Forward Link BS MAC Transmissions in relation to the Reverse Link MS Transmission Time Slots;

Fig. 4 is a logic flow diagram, according to the invention, for a MS to predict its next allocation of a token;

Fig. 5 is a state flow diagram, according to the invention, for MS packet operation; and

Fig. 6 is a state flow diagram, according to the invention, for BS packet operation.

Reference is first made to Figs. 1 and 2 for illustrating a wireless user terminal or mobile station (MS) 10, such as but not limited to a cellular radiotelephone or a personal communicator, that is suitable for practicing this invention. The MS 10 includes an antenna 12 for transmitting signals to and for receiving signals from a base site or base station (BS) 30. The BS 30 is a part of a cellular network 32 that includes a mobile switching center (MSC) 34, and a plurality of additional BSs, such as BS 30'. Each BS, for example BS 30, services an associated cell within the network 32 and is assumed to include a plurality of receivers 30a and transmitters 30b, some of which can be allocated for packet data services. The MSC 34 provides a connection to landline trunks when the mobile station 10 is involved in a call. It is assumed for the purposes of this invention that the network 32 supports packet data service. For example, the network 32 may be coupled to a packet data network 36 such as the internet, and/or to a LAN or WAN.

The mobile station includes a modulator (MOD) 14A, a transmitter 14, a receiver 16, a demodulator (DE-

a controller 18 that provides signals to
nals from the transmitter 14 and receiv-
ly. These signals include signalling in-
ordance with the air interface standard
cellular system, and also user speech
erated data. The air interface standard
this invention to include a capability to
data.

ently preferred embodiment of this inven-
tor 14A, transmitter 14, receiver 16, and
5A are adapted to operate with a code
e access (CDMA) system, such as one
95A. The teaching of this invention is not,
id for use with only this type of system,
nployed with a number of different types
aving different modulation and access
, such as time division, multiple access
ms.

stood that the controller 18 also includes
quired for implementing the audio and log-
the mobile station. By example, the con-
be comprised of a digital signal processor
roprocessor device, and various analog to
ters, digital to analog converters, and other
ts. The control and signal processing func-
obile station are allocated between these
rding to their respective capabilities.
bile station 10 may be capable of voice
s also, and thus can include a user inter-
sed of a conventional earphone or speaker
ntional microphone 19, a display 20, and a
evice, typically a keypad 22, all of which are
e controller 18. The keypad 22 includes the
l numeric (0-9) and related keys (#,*) 22a,
ys 22b used for operating the mobile station
other keys 22b may include, by example, a
various menu scrolling and soft keys, and a
The mobile station 10 may also include a bat-
owering the various circuits that are required
the mobile station.
ld be realized that in other embodiments the
tion 10 may function only as a data terminal
one of transmitting or receiving packet data.
e station 10 which functions as a data terminal
e a data port 28 which is coupled to the con-
As a data terminal, certain of the user interface
nts described above may not be included. It
so be appreciated that in some embodiments
e station 10 may not be mobile at all, but may
ed at a fixed location (for example, as a com-
f a wireless facsimile machine in an office en-
nt).
mobile station 10 also includes various memo-
wn collectively as the memory 24, wherein are
plurality of constants and variables that are
the controller 18 during the operation of the mo-
ion. For example, the memory 24 may store the
of various cellular system parameters and the
number assignment module (NAM). An operating program for controlling the operation of controller 18 is also stored in the memory 24 (typically in a ROM device). The memory 24 may also store packet data prior to transmission or after reception. The memory 24 includes routines for implementing the methods described below in relation to Figs. 4, 5 and 6.

Packet data service options provide a mechanism of establishing and maintaining traffic channels for packet data service. A packet data service option is negotiated during call origination or at a later time during a call. The details of establishing packet data service can be found in, by example, IS-95A, IS-657, and IS-99.

In accordance with this invention, the call origination messages are modified from the definitions in the above mentioned standards to include a MAC channel frame structure as shown in Fig. 3A. The MAC channel frame structure is broadcast by the BS 30 to all MSs 10 within the cell at regular intervals of time, referred to as a MAC transmission period. The BS 30 divides access to the traffic channel(s) allocated for packet data services according to time slots. A time slot is defined as the time period required for a MS to transmit all or some of its packet data. A time slot is limited to the maximum transmission time set by the BS 30. Time slots may be of unequal duration, as each time slot's duration can be defined by the amount of packet data a MS 10 is transmitting, up to a maximum transmission time. Additionally, one or more MAC transmission periods may elapse within a time slot, however, each time slot has a duration that is a whole multiple of the duration of the MAC transmission period. The relationship between time slots and MAC transmission periods is illustrated in Fig. 3B. In essence, the time slot represents a given period of time in which a MS 10 has the right to access a traffic channel. The MS 10 that is allocated this access right is allocated a token. The MAC channel frame structure contains various fields that are used by the BS 30 to schedule traffic channel access, i.e. token allocation. As is shown in Fig. 3B, a portion of an assigned time slot may be unused by a MS 10.

The MAC channel frame structure includes a plurality of one bit wide fields, *1 to n*. These fields are referred to as "activity" fields. Each activity field defines the status of a corresponding MS 10, and may have a value of either zero ("0") or one ("1"). A field value of zero indicates that the corresponding MS 10 has not been assigned to a traffic channel by the BS 30. A field value of one indicates that either the MS has been assigned to receiver hardware in the BS 30, or that the activity field is not currently assigned to any MS within the cell. In the preferred embodiment the activity field is a one bit wide field, however, a field width of more than one bit may be used for conveying the activity status information of one or more MSs 10.

Additionally, each activity field corresponds to a temporary identification number that is assigned by the BS 30 to the MSs 10 for purposes of media access con-

hese temporary identification numbers are re- to as MAC IDs. The BS 30 allocates a different ID, and hence a different corresponding activity o each MS 10 within the cell. A MAC ID is valid BS 30 that assigns it, and multiple BSs 30 may assign different MAC IDs to the MS 10 in order to rt virtual "soft handoff". Thus, each packet may be via a different BS 30, but never via more than one one packet, depending on the signal condition to/ hat BS. The virtual soft handoff is preferably mossisted and is based on the pilot signal condition by the MS 10, in the similar manner as in conven- soft handoff procedures.

According to the embodiments of this invention, the al soft handoff procedure differs from conventional handoff procedures. In conventional soft handoff edures, the traffic channel is handoff from a first BS second BS. In accordance with this invention, the- ile station's monitoring of the MAC channel is hand- om the MAC channel of the first BS 30 to the inde- dent MAC channel of the second BS 30'. In other ds, the MS 10 is first receiving MAC information from MAC channel of the first BS 30. At some point, the 10 will be receiving the MAC channel of the first BS as well as the MAC channel of the second BS 30'. ause token allocation and scheduling information is ntained within the MAC information the MS may re- ve a token from either BS 30 or 30' and transmit to BS during the virtual soft handoff process. Once a en is received it is held until transmission is complet-

For example, a token received from the first BS 30 es not give the MS 10 the right to transmit to the sec- d BS 30'. Additionally, there may be an occurrence en a token is simultaneously offered by both BSs, 30 d 30', servicing the MS 10. In this event, the MS 10 eferably accepts the token that is allocated by the est" quality channel (e.g. lowest bit error rate or frame or rate) and transmits the packet data to the associed BS 30 or 30'. When the pilot signal of the first BS) drops below a predetermined level the MS 10 drops e MAC channel of the first BS 30 and monitors only e MAC channel of the second BS 30'. After the MS 10 ops the first BS 30, the first BS 30 is free to reassign e MAC ID it previously assigned to the MS 10.

Because every packet MS 10 has its own MAC ID e total number of required MAC IDs could become exessively large for a large cell. Therefore, packet users ay be divided into MAC sub-groups, and MAC ID numers can be reused within the sub-groups of different channels.

MAC IDs are preferably allocated by the BSs 30 during a "virtual call set-up" procedure. The BS 30 that performs the virtual connection is preferably the BS from which the MS 10 receives the strongest pilot signal. This invention assumes that the interworking function (IWF) that has been established with a fixed packet data network, e.g. internet, resides in the mobile network, not at the first BS where the MS sets up the virtual connection. That is, the IWF in the MSC 34 is connected to two or more BSs.

The MAC channel frame structure also includes a *Next MAC ID* field. This field is an n-bit wide field, where n represents a number of bits which can accommodate the maximum allowable width of the MAC ID field. The Next MAC ID field indicates which MS(s) 10 are allowed to transmit data during the next time slot, i.e. who will have the next token. The Next MAC ID field is sent in each MAC frame message. As a result, if any MSs 10 miss one or more MAC frames they are enabled to quickly determine the access token rotation.

Lastly, the MAC channel frame structure includes a *#Free Channels* field. This field is an m-bit wide field, where m represents a number of bits which can accommodate an integer that indicates the maximum number of traffic channels within a BS that are allocated for packet data transmission. The value of the #Free Channels field indicates the number of currently available traffic channels in the BS 30 in a given time slot.

In accordance with this invention, and referring to Figs. 3A and 4, a MS 10 evaluates the fields within the MAC channel frame structure and predicts when it will be allocated a token. A MS 10 accomplishes this prediction in the following manner. First, at Block A, an initialization step for a counting process is performed. This initialization step evaluates the MAC channel frame structure and locates, within the MAC channel frame, the activity field that corresponds to the MS 10 whose MAC ID is equal to the value of the Next MAC ID field. Additionally, the initialization step sets to a value of zero a variable which represents the result of the counting process. The counting process is performed at Blocks B through D inclusive. Within the process a predicting MS 10 counts, in a cyclic manner, activity fields within the MAC control frame structure with values of zero. At Block B, the counting process starts at the Next MAC ID's activity field position and, moving from left to right, retrieves the next activity field in the MAC control frame whose value is zero. At Block C, this retrieved activity field is evaluated to determine whether it corresponds to the MAC ID of the predicting MS 10. If this retrieved activity field corresponds to the MAC ID of the predicting MS 10 then the counting process is complete, and the prediction algorithm continues at Block E. However, if the retrieved activity field does not correspond to the predicting MS, then the variable which represents the counting result is incremented by one at Block D. Note, because the accounting process begins after retrieval of the activity field which corresponds to the Next MAC ID, this activity field is excluded from the count. The counting process will cycle through Blocks B, C, and D until the activity field corresponding to the predicting MS 10 is encountered, i.e. the condition evaluated in Block C is "YES".

After the counting process has completed, the prediction procedure continues, at Blocks E and F, by performing a calculation which uses the current value of the

Channels field and the counting variable defined
For purposes of illustration, if the predicting MS
signs the result of the counting process to a vari-
", and assuming the current #Free Channels field
gned to a variable "M", the calculation at Blocks
F is represented by the following formula:

$$y = INT(x/M) + 1. \quad (1)$$

current slot number is j, then the (j + y)th slot is the
cting MS's turn to have the token. Also, this implies
the predicting MS's position is within M - 1 zero
f the MS corresponding to the Next MAC ID, then
en will be allocated to the predicting MS in the next
because a traffic channel will be available.
n the minimum form, the prediction of token usage
ly valid for the next time slot. That is, the BS 30 may
te the token allocation information every time slot.
duce the MS's 10 receiving activity, the BS 30 may
se to update the token allocation information differ-
so that the calculation from Equation (1) is valid
ne next x time slots, or a time period referred to as
per-frame. Consequently, the MS 10 does not have
ecode the MAC message in every time slot in order
to miss its turn for transmission. The super-frame
period is controlled by the BS 30.
In accordance with this invention, and referring to
5, packet MS operation is as follows. Whenever a
10 with packet data service mode activated enters
cell, or when a MS 10 in the cell activates packet
a mode, the BS 30 assigns a MAC ID number, and
s a corresponding activity field, to the MS 10. This
signment, referred to as virtual call set-up, is shown
Block A. At Block B, the MS 10 stores the temporary
AC ID in the memory 24.
Once the MAC ID and activity field are assigned,
MS 10 decodes the broadcast MAC messages sent
m the BS 30. This decoding, shown at Block C and
continues until the MS 10 determines that it was al-
cated the token by the BS 30. Allocation of the token
ables the MS 10 to transmit its packet data. However,
Block E, the MS 10 must first determine whether it
as packet data to send. If the MS 10 does not have
acket data to send it continues to decode MAC mes-
ages and the BS 30 will allocate the token to the next
IS 10 in the subsequent time slot. If the MS 10 does
ave data to transmit then it begins a transmission proc-
ss as shown in Blocks F through I. First, at Block F, the
MS 10 transmits a preamble message on the reverse
ink to the BS 30. If the BS 30 receives the preamble it
eplies with an acknowledgment. If the acknowledgment
s received then the MS 10, as shown in Blocks G and
H, transmits its packet data. The transmission continues
until all MS 10 packet data is sent, or a maximum
number of bytes to transmit is surpassed, or a predeter-
mined time-out period is exceeded, shown in Block H
and I. If the maximum number of bytes to transfer is en-
countered or the time-out period is exceeded, transmis-
sion may be stopped and the transmitting MS 10 re-
turned to the decoding step, Block C, described above.
However, if packet data transmission is successful the
packet data call is terminated, the transmission process
is complete, and the token is allocated by the BS 30 in
the subsequent time slot to the next MS 10 in the cell.
In accordance with the present invention, the BS 30
allows the MS 10 to turn off its receiver and save power
during the periods when the MS is not allocated the to-
ken. If the MS 10 does shut down its processing be-
tween tokens, the BS 30 informs the MS 10, before the
MS 10 shuts down, when it should start its processing
again, i.e. when the MS 10 will be allocated the token
again. This notification by the BS 30 before the MS 10
shuts down is possible as the token is assigned in ad-
vance. Thus, a "dynamic slotted mode" operation is pro-
vided, the operation being dynamic in that the position
of the slot need not be the same in every cycle. The slot
position is a function of how many active MSs 10 are on
the channel, and on how much data each MS 10 can
transmit. Additionally, the number of slots is a function
of the number of available channels at the BS 30.
The BS 30 may transmit packets destined for a MS
10, if any, or fill data, on the forward link at the same
time that the MS 10 is allocated a token and is transmit-
ting packets on the reverse link. This allows the BS 30
to send power control information to the MS 10.
In accordance with this invention, and referring to
Fig. 6, packet BS 30 operation is as follows. Note, Fig.
6 assumes that the BS 30 has divided traffic channel
access into the discrete time periods referred to above
as time slots. Thus, BS 30 operation, as shown in Fig.
6, begins when a MS 10 activates packet data mode. At
Block A, the BS 30 assigns a MAC ID number and ac-
tivity field to the MS 10 with packet data mode active,
this assignment is referred to as virtual call set-up. In
virtual call set-up, the BS 30 initially assigns the activity
field corresponding to the MS 10 a value of one. On the
subsequent MAC frame, shown at Block B, the BS 30
sets this activity field value to zero, which indicates that
the MS 10 of the newly assigned MAC ID is in the queue
for access to a traffic channel. Whenever a MS 10 with
packet data service mode active leaves the cell, or de-
activates the packet data mode, the BS 30 release the
MAC ID number from the MS 10 and, in the subsequent
MAC message, the BS 30 sets the corresponding activ-
ity field of the released MAC ID to one, thus dequeuing
the MS 10 from traffic channel access.
At Block C, the BS 30 evaluates the queue of MSs
10 awaiting a token. If no MSs are waiting, the schedul-
ing process is complete. However, if one or more MSs
remain queued for access, the BS determines a sched-
uling sequence. At Block D, a scheduling algorithm is
employed which considers one or more parameters in-
cluding, for example, prioritized access, service quality
factors, and a maximum number of bytes to transmit by
each MS 10. Once a schedule is determined which en-

sures efficient packet data transmission the BS 10 updates the MAC control structure frame to reflect the schedule.

The BS 30 performs this updating, shown at Block E, as follows. A change in token scheduling status begins when the BS 30 cycles the value assigned to the Next MAC ID field to identify the MAC ID of the MS 10 that is to be allocated the token in the next time slot. Once this MS 10 is allocated the traffic channel and begins transmission of its packet data the BS 30 updates the MS's corresponding activity field to a value of one, decreases the value of the #Free Channels field by a value of one, and reassigns the value of the Next MAC ID field to identify the MS 10 that is to transmit its packet data in the next time slot.

This cyclic assignment can be further demonstrated by considering the MAC control frame structure fields in both an inactive and active state. In the inactive state, when there are no packet data MSs 10 within a cell, all activity fields of the MAC control structure frame are a value of one, the Next MAC ID field has a value of zero, and the #Free Channels field has a value equal to the maximum number of receivers 30a in the BS 30 that are allocated for packet services. In the active state, after the BS 30 has assigned a unique MAC ID to each packet mode MS 10 in a cell, the MAC control frame activity fields corresponding to the assigned MAC IDs without a token are a value of zero, the Next MAC ID field is a value which corresponds to the MAC ID of the MS 10 that is scheduled to be allocated a token in the next time slot, and the #Free Channels field is a value which represents the number of receivers 30a in the BS 30 that support packet service, less the number of channels occupied by MSs 10 that currently are allocated the token or tokens. Note, the BS 30 decreases the value of the #Free Channels field by one whenever a MS 10 successfully acquires a traffic channel and starts to transmit packet data. Likewise, the BS 30 increases the value of the #Free Channels field by one when the traffic channel is released at the end of packet transmission. Thus, the transmission schedule is defined by the values of the MAC control frame structure fields.

At Block F, the BS 30 broadcasts the MAC control frame structure to each MS 10 within the cell. As discussed above, when broadcasting MAC channel messages to all MSs 10 within a cell the BS 30 preferably uses a public long code mask, and when transmitting the MAC channel messages to a specific MS 10 the BS 30 may use a permuted electronic serial number (ESN) of the MS 10 as a long code mask.

The MS 10 decodes the MAC message and evaluates the MAC control frame fields to determine the traffic channel access schedule. To ensure preemptive control of channel access the BS 30 monitors, at Block G, the transmissions of the MS 10 that is allocated the token. For example, at Block H, if the maximum number of bytes per transmission is exceeded the BS 30 may force the termination of the MS 10 transmission and return the MS to the queue for token assignment. If the MS 10 transmission completes, as shown in Block I, the BS 30 reallocates the token in the next time slot. This reallocation process is accomplished by looping back to the above evaluation of MSs awaiting packet data transmission permission, Blocks C through I. If transmission is not complete, the BS 30 may rebroadcast the MAC message and continue to monitor the MS's transmission. This scheduling process continues until there are no packet data MSs queued for transmission, i.e. all MS packet data transmissions are complete.

It should be realized that a plurality of MSs 10 could each be allocated a token, giving the mobiles the right to access respective available traffic channels in the BS 30, in a given time slot. By example, if there are n available traffic channels, upto n mobile stations can be granted the token to transmit during a next time slot.

While the invention has been particularly shown and described with respect to preferred embodiments thereof, it will be understood by those skilled in the art that changes in form and details may be made therein without departing from the scope and spirit of the invention.

Claims

1. A method for transmitting packet data from a plurality of mobile stations to a base station, comprising the steps of:

   broadcasting media access control (MAC) information from the base station to the plurality of mobile stations;

   receiving the broadcast MAC information at the plurality of mobile stations; and

   for a mobile station specified in the MAC information, transmitting packet data to the base station at a time specified by the MAC information.

2. A method as in claim 1, wherein a set of the mobile stations transmit their respective packet data over a same traffic channel at different times, as specified by the MAC information.

3. A method as claimed in claim 1 or 2, wherein the step of broadcasting uses a dedicated MAC channel.

4. A method as claimed in any of claims 1 to 3, wherein the base station transmits packet data destined for the mobile station on a forward link at the same time the mobile station transmits packet data on the reverse link.

5. A method as claimed in any of claims 1 to 4, wherein the MAC information comprises a MAC control frame structure for conveying packet data transmission scheduling information, the MAC control frame structure including a plurality of activity fields, one activity field for each active packet data mobile station within a cell, a Next MAC ID field which specifies the identification of a mobile station to be given traffic channel access in a next time slot, and a #Free Channels field which specifies a number of available traffic channels for packet data service at the base station.

6. A method as in claim 5, wherein the identification of the mobile station is by a temporary number (MAC ID) that is assigned to the mobile station by the base station.

7. A method as claimed in any of claims 1 to 6, wherein transmissions of packet data from the mobile station to the base station are preemptively controlled and scheduled by the base station.

8. A method as claimed in any of claims 1 to 7, wherein the base station transmits MAC information to a specific mobile station using a permuted electronic serial number (ESN) of the mobile station as a long code mask, and broadcasts MAC information to all mobile stations within a cell using a public long code mask.

9. A method as claimed in any of claims 1 to 8, wherein transmissions between the base station and mobile stations employ spreading codes, a unique spreading code to identify transmissions to each mobile station individually, and a public spreading code to identify a broadcast to all mobile stations.

10. A method as claimed in any of claims 1 to 9, wherein a base station of an original cell and a base station of a new cell both receive a transmission from a mobile station during a transition period from the original cell to the new cell.

11. A cellular communication system, comprising:

a plurality of base stations, each base station having an associated cell;

a plurality of mobile stations located within said cells;

means in each said base station for broadcasting media access control (MAC) information from said base station to mobile stations located within the base station's cell;

each of said mobile stations comprising a receiver for receiving said broadcast MAC information; and

each of said mobile stations further comprising a controller, responsive to said broadcast MAC information, for transmitting packet data from said mobile station to said base station at a time specified by the received MAC information.

12. A system as in claim 11, wherein a set of said mobile stations transmit their respective packet data over a same traffic channel at different times, as specified by said MAC information.

13. A system as claimed claim 11 or 12, wherein said means for broadcasting uses a dedicated MAC channel.

14. A system as claimed in any one of claims 11 to 13, wherein said receiver receives a dedicated MAC channel using a predefined spreading code.

15. A system as claimed in any one of claims 11 to 14, wherein said base station transmits packet data destined for said mobile station on a forward link at the same time said mobile station transmits packet data on the reverse link.

16. A system as claimed in any one of claims 11 to 15, wherein said MAC information comprises a MAC control frame structure for conveying packet data transmission scheduling information, said MAC control frame structure including a plurality of activity fields, one activity field for each active packet data mobile station within said cell, a Next MAC ID field which specifies said identification of said mobile station to be given traffic channel access in a next time slot, and a #Free Channels field which specifies a number of available traffic channels for packet data service at said base station.

17. A system as claimed in any one of claims 11 to 16, wherein transmissions of packet data from said mobile station to said base station are preemptively controlled and scheduled by said base station.

18. A system as claimed in any one of claims 11 to 17, wherein said base station transmits MAC information to a specific mobile station using a permuted electronic serial number (ESN) of said mobile station as a long code mask, and broadcasts MAC information to all mobile stations within a cell using a public long code mask.

19. A system as claimed in any one of claims 11 to 18, wherein transmissions between said base station and said mobile stations employ spreading codes, a unique spreading code to identify transmissions

to each mobile station individually, and a public spreading code to identify a broadcast to all mobile stations.

20. A system as claimed in any one of claims 11 to 19, wherein said base station of an original cell and said base station of a new cell temporarily receives a transmission from said mobile station during a transition period from the original cell to a new cell.

21. A method of scheduling the wireless transmission of packet data between a mobile station and a base station, comprising the steps of:

assigning an identification to and an activity status for each packet data service mobile station within a cell;

setting the activity status of the packet data service mobile station for queuing the mobile station for packet data transmission;

scheduling packet data transmission times for multiple queued mobile stations;

activating with a media access control (MAC) message a queued mobile station by assigning, with the identification, a right to transmit packet data;

updating the activity status and activation scheduling information in a next MAC message;

broadcasting with a MAC message a packet data transmission scheduling sequence which comprises the updated activity status and activation information to each active packet data service mobile station;

decoding in each active packet data service mobile station the broadcast activity status and activation information to determine the scheduling sequence;

predicting a time period when the mobile station has permission to transmit packet data by evaluating the decoded activity status and activation information; and

transmitting packet data during the predicted time period according to the broadcast scheduling sequence.

22. A method as set forth in claim 21, wherein the step of scheduling is performed after evaluating one or more parameters including prioritized access, service quality considerations, and maximum number of bytes to transmit.

23. A method as set forth in claim 21 or 22, wherein the base station identifies the mobile station with a temporary number (MAC ID), the MAC ID is valid for the base station that assigns it and multiple base stations may assign different MAC IDs to the mobile station.

24. A method as set forth in claim 23, wherein a plurality of mobile stations are identified as a sub-group, each sub-group reusing MAC IDs assigned by a base station to mobile stations within a different sub-group.

25. A method of scheduling transmission of channel packet data between a packet data source and a packet data sink in a wireless transmission/reception system, comprising the steps of:

establishing time slots for transmitting packet data by dividing access to traffic channels allocated for packet data communication into discrete time periods;

establishing an identification number (MAC ID) for packet data sources to be used for packet data transmission;

associating an activity field with each MAC ID;

using a MAC control frame structure to convey packet data transmission scheduling information from the packet data sink to queued packet data sources, wherein the scheduling information includes activity fields, a Next MAC ID field which specifies a packet data source having a MAC ID to be given traffic channel access in a next time slot, and a count of a number of free traffic channels available at the packet data sink;

activating a queued data source by assigning the Next MAC ID field the value of the data source's MAC ID, thus granting a right to transmit packet data in the next time slot;

updating the activity field of the activated data source and decreasing the count of the number of free traffic channels;

broadcasting the MAC control frame structure to all packet data sources;

predicting at the packet data source the time slot when a given packet data source can transmit packet data by evaluating the MAC control frame structure; and

itting the packet data according to the
/transmission scheduling sequence de-
ithin the MAC control frame.

as set forth in claim 25, wherein the base
iodically updates the information con-
ne MAC control frame structure.

as set forth in claim 25 or 26, wherein the
edicting when a given packet data source
tive further comprises the steps of:

iting in a cyclic manner, a number of zero
ed bits in the activity fields of the MAC con-
frame structure from left to right starting
n, but excluding the position of the Next
C ID to the MAC ID position of the given
cket data source

rieving the #Free Channels field from the
AC control frame structure

viding the count of zero valued activity fields
om the position of the Next MAC ID to the po-
ition of the given packet data source by the
Free Channels field and

adding the integer quotient from the division
performed in the step above and the number
one, this value plus the current slot number rep-
resenting the time slot in which the predicting
packet data source is to transmit packet data.

ethod as set forth in any one of claims 25 to 27,
erein the steps of transmitting occur over a code
ision multiple access (CDMA) packet data chan-
l.

FIG. 1

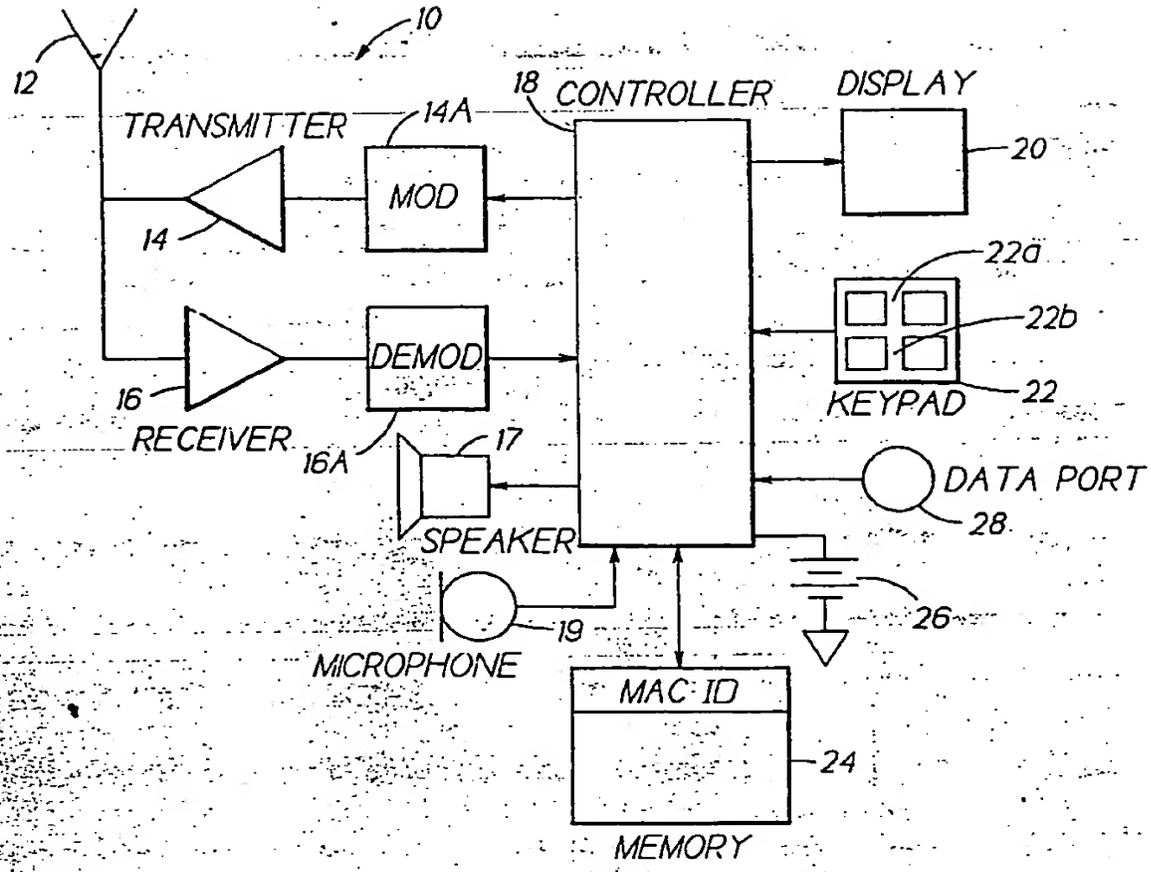
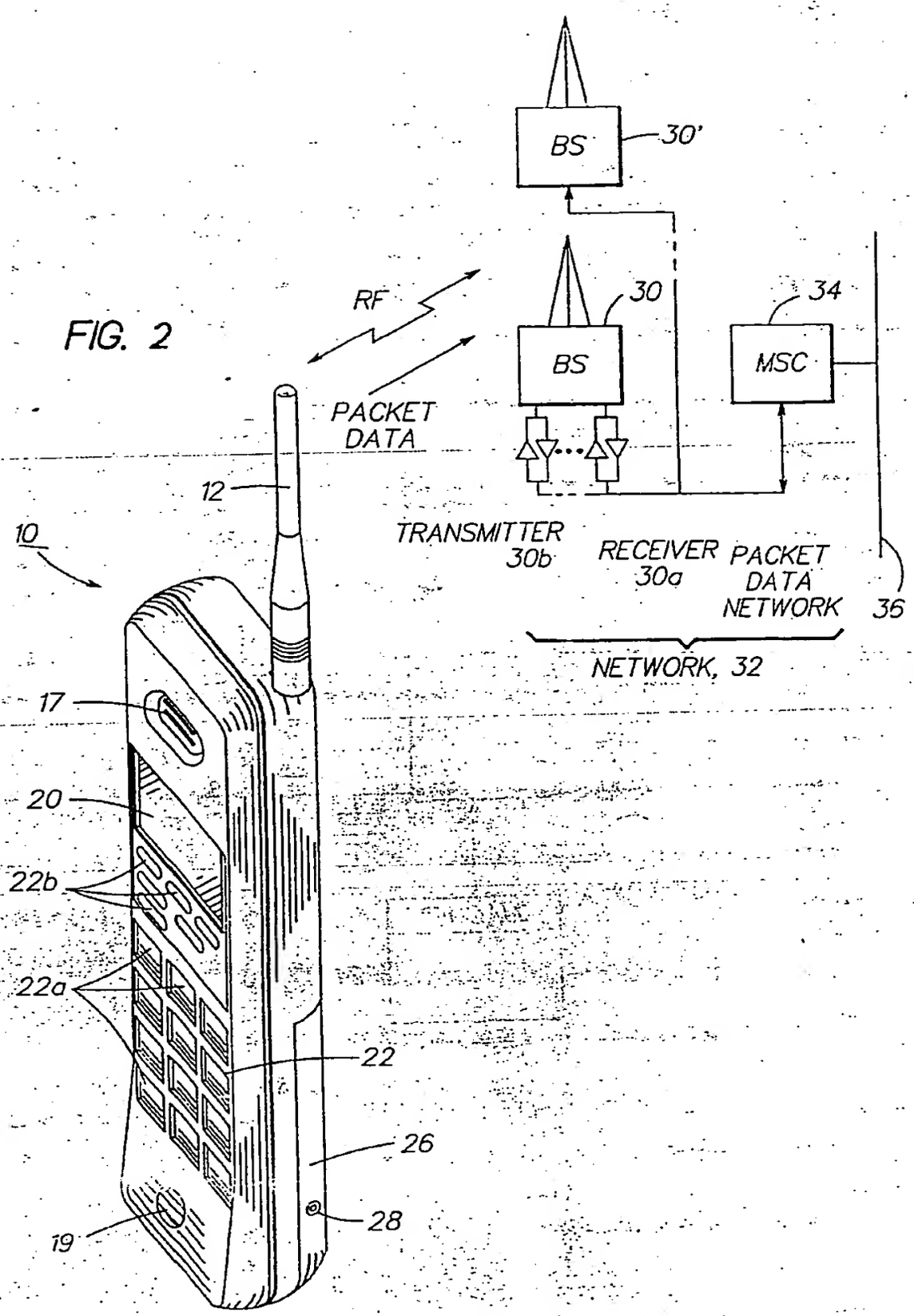


FIG. 2



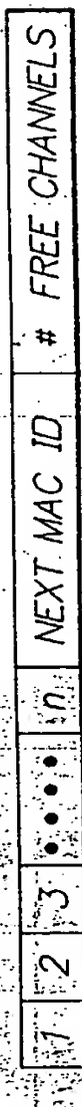


FIG. 3A

FIG. 3B

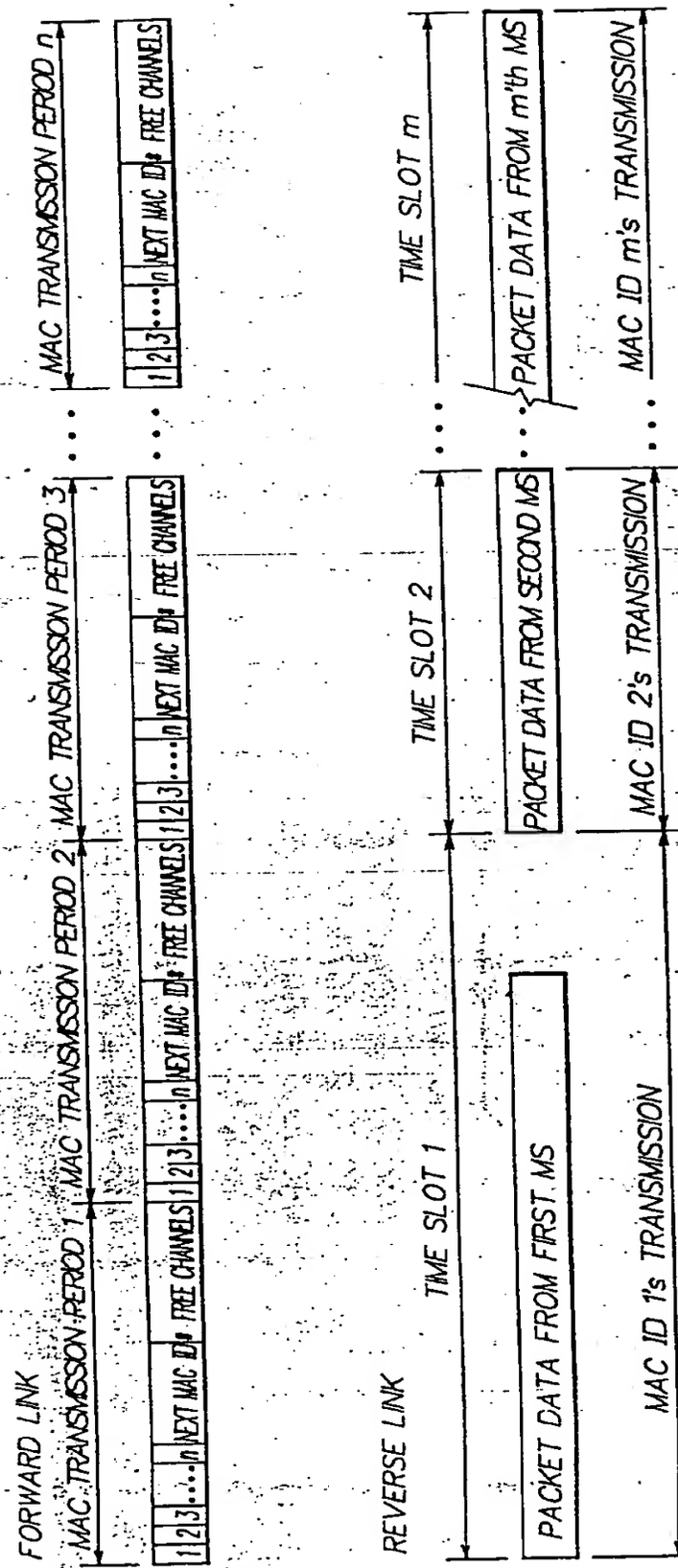


FIG. 4

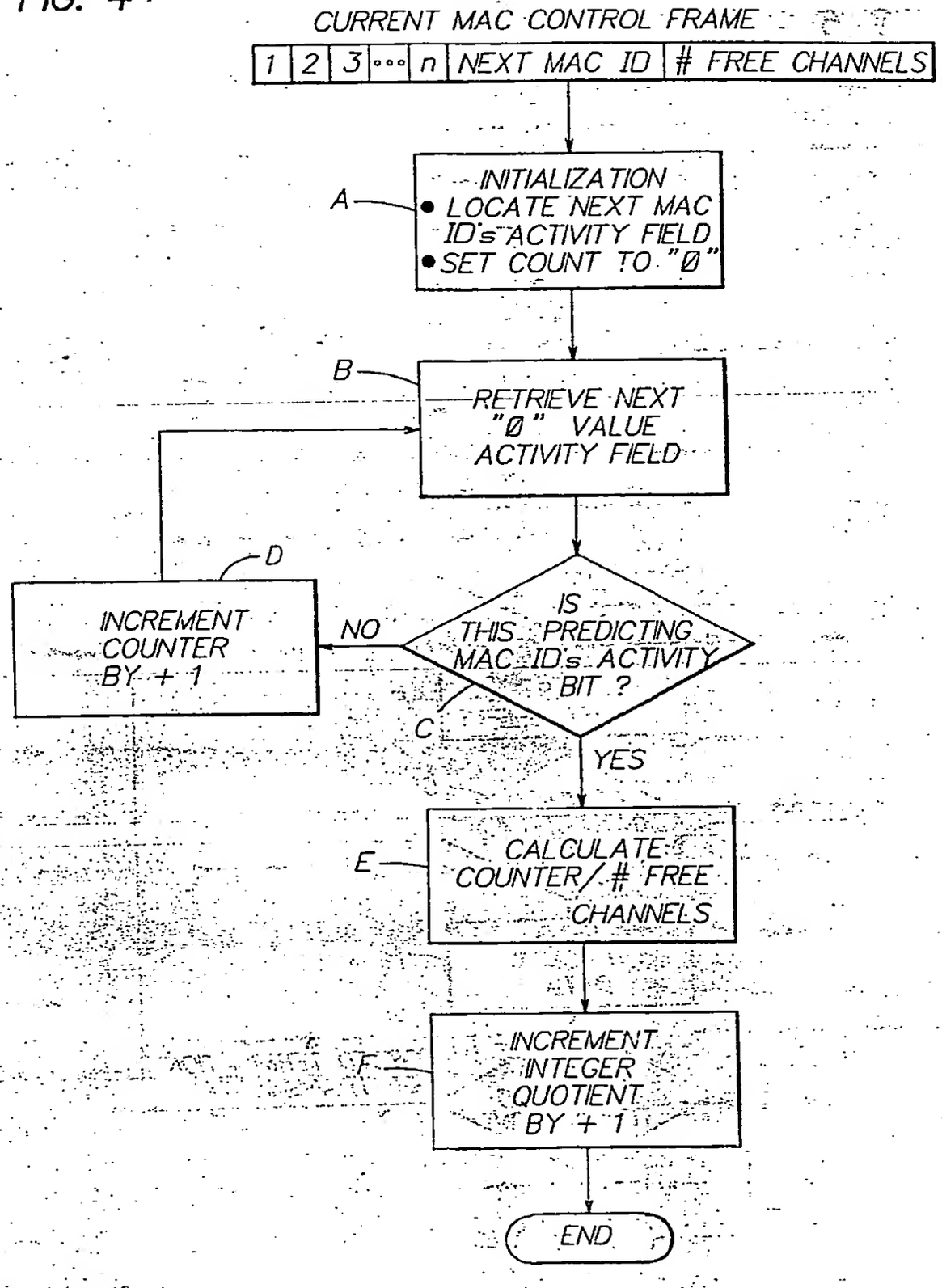


FIG. 5

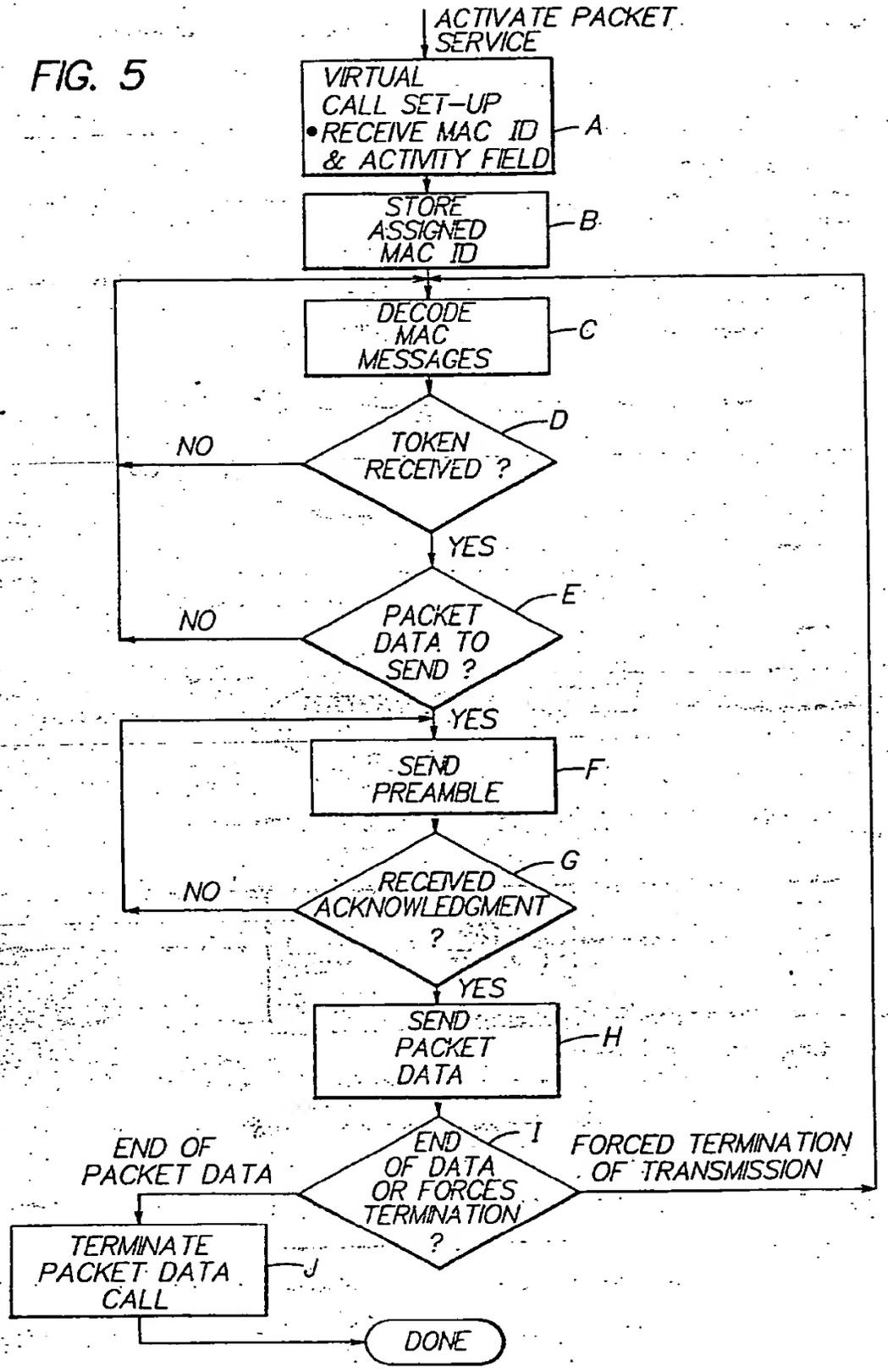
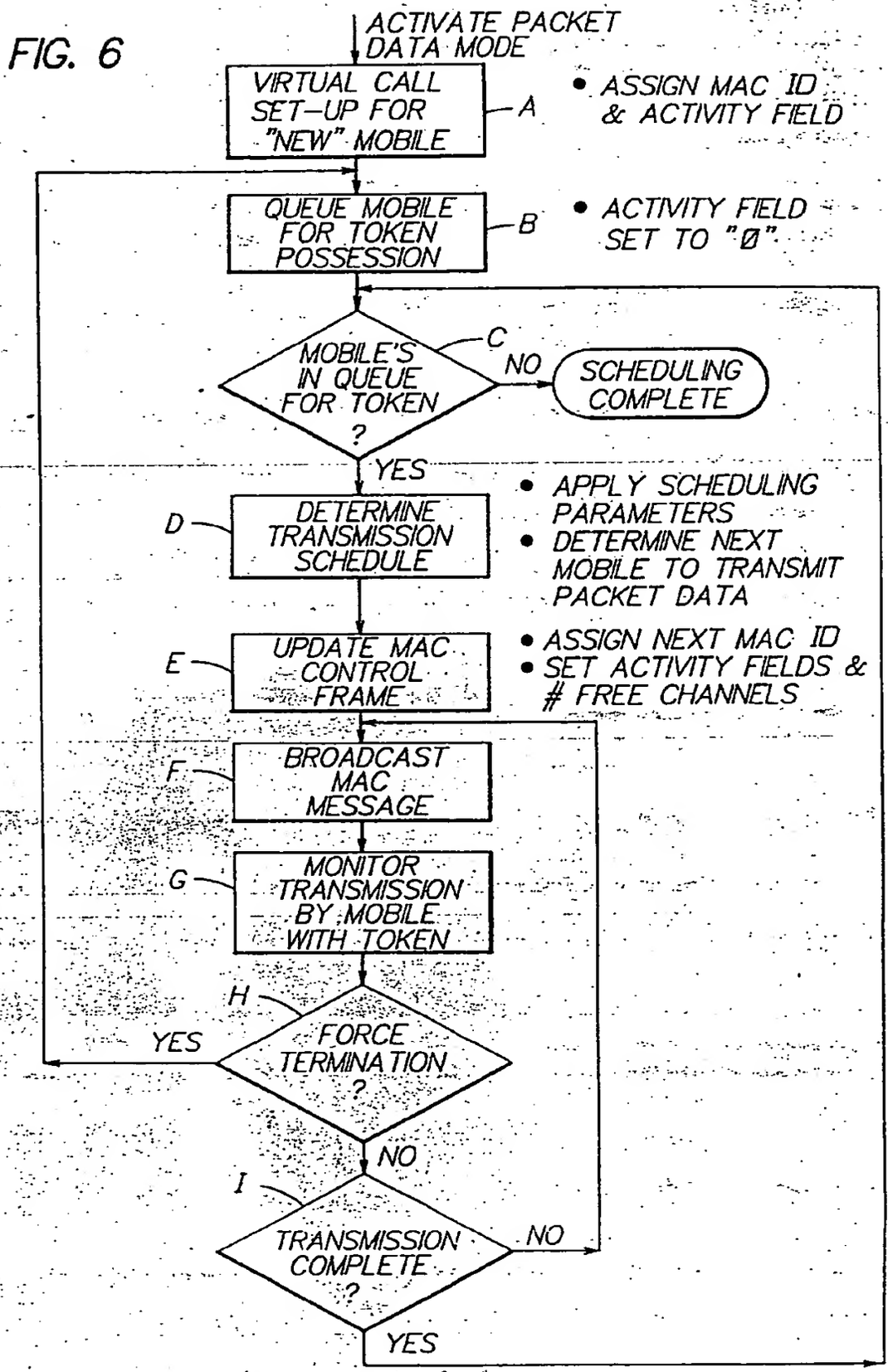


FIG. 6



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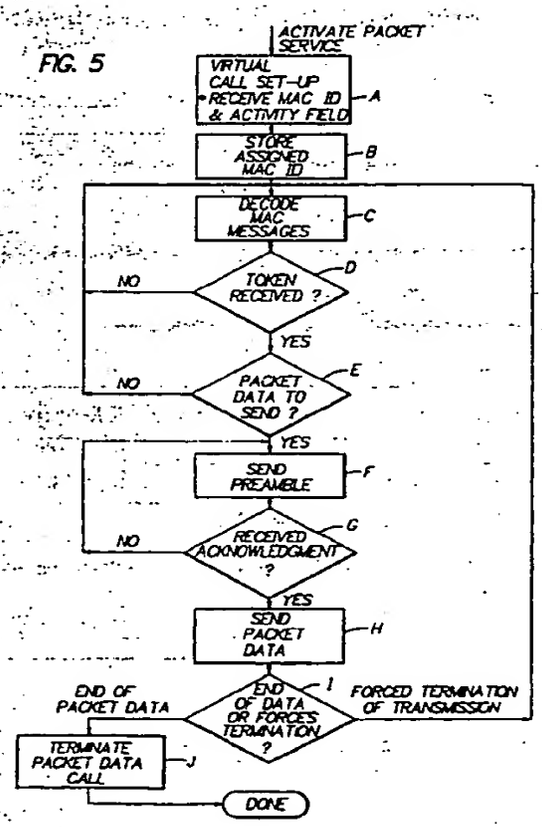
(54) A method for scheduling packet data transmission

(57) In a packet data transmission and reception system a media access control (MAC) message is broadcast by a base station to a plurality of mobile stations. The MAC message contains packet data transmission scheduling information which allows the base station to preemptively control mobile station access to traffic channels in order to maximize the efficiency of packet data transmissions and allow scheduling consideration including priority access, quality of service and maximum bytes per transfer. The MAC message consists of a control frame structure which comprises scheduling parameters including MAC IDs fields, activity fields, and a field representing the number of free traffic channels in a cell. These parameters enable multiple mobile stations to share, in a time multiplexed fashion, traffic channels for packet data transmission on CDMA based mobile communication systems.

FIG. 5



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EUROPEAN SEARCH REPORT

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EP 98 30 3427

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
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X	US 4 491 947 A (FRANK AMALIE J) 1 January 1985 (1985-01-01) * column 9, line 64 - column 10, line 26 *	1-3,7, 11-13, 17,21, 22,25	
A	WALKE B ET AL: "WIRELESS ATM: AIR INTERFACE AND NETWORK PROTOCOLS OF THE MOBILE BROADBAND SYSTEM" IEEE PERSONAL COMMUNICATIONS,US,IEEE COMMUNICATIONS SOCIETY, vol. 3, no. 4, 1 August 1996 (1996-08-01), pages 50-56, XP000623675 ISSN: 1070-9916 * page 52, right-hand column, line 20 - page 53, right-hand column, line 2 *	1-3,7, 11-13, 17,21, 22,25	

TECHNICAL FIELDS SEARCHED (Int.Cl.6)
H04L
H04Q

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	3 October 2000	Weinmiller, J

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